

LATE PRECAMBRIAN PSEUDOFOSILS FROM THE FLINDERS RANGES, SOUTH AUSTRALIA

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Summary

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Enigmatic, subcylindrical to conical, sediment-infilled structures occurring in the Trezona Formation and the lower and upper parts of the Moorillah Formation of the late Precambrian of the central Flinders Ranges, South Australia, resemble certain fossil burrows such as *Bergaueria* Prantl, and also late Precambrian body fossil remains including the sack-shaped, soft-bodied form *Ernieita* Pflug from South West Africa (Namibia). The structures occur up to 3,300 m stratigraphically below the well known Ediacara assemblage. The lack of disruption or vents in their matrix seemingly negate the possibility that they are water escape structures, but studies of their infilling and literature research indicate that their true origin is almost certainly inorganic, their resemblance of various fossil remains being fortuitous. Their recognition emphasizes the apparent non-occurrence of metazoan remains below the Ediacara assemblage in the local rock record, lending negative support to recent theories postulating either late evolution of the Metazoa or rapid diversification of animal life in the latest Precambrian.

Introduction

In 1975, a discovery of abundant, peculiar cylindrical structures was made by Moriarty in the lower part of the Moorillah Formation (Plummer 1978) in Utanouna Creek, within the Bunbinyunna Range, south-west of Wilpena Pound in the Flinders Ranges (Fig. 1). At the time he considered that the structures may have been biogenic. During late 1976, in the course of extensive field mapping of the Brachina Subgroup, Plummer found a comparable structure in float within Bunyerroo Creek, and later a second specimen only a few kilometres from the original find of Moriarty. This latter specimen was shown to Jenkins who noticed a radial pattern of markings on the base of the (short) column, and longitudinal striations on its sides. As such, the form showed a resemblance to the Cambrian to Jurassic trace fossil *Bergaueria* Prantl, and also to various late Precambrian metazoan remains. Subsequent exploration has widened the known distribution of the structure and confirmed its constancy of general form and the more or less stable sedimentological characteristics attending its preservation.

Two specimens of similar structures in stratigraphic collections of the University of

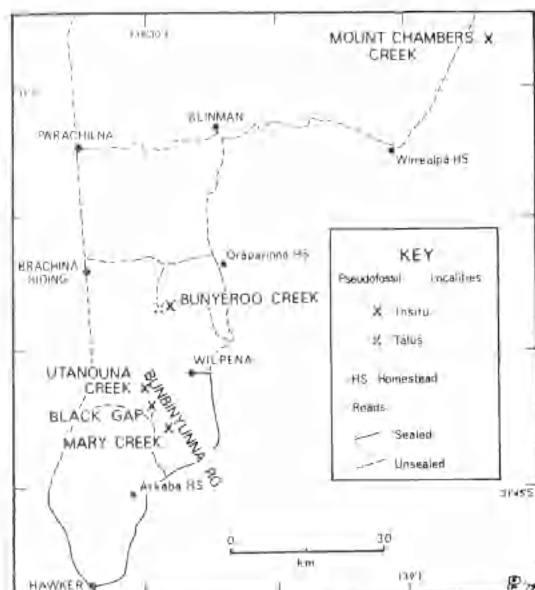


Fig. 1. Locality map of pseudofossil occurrences in central Flinders Ranges, South Australia.

Adelaide were found by M. A. Reynolds in 1950 west of "Bunyerroo Hut" (probably Yanyanna Hut on current maps) apparently within the Trezona Formation of the Umberatana Group.

Stratigraphy

The Trezona Formation reaches a thickness of about 240 m in the Orparinna area and consists of mud flake rich pelletal limestones,

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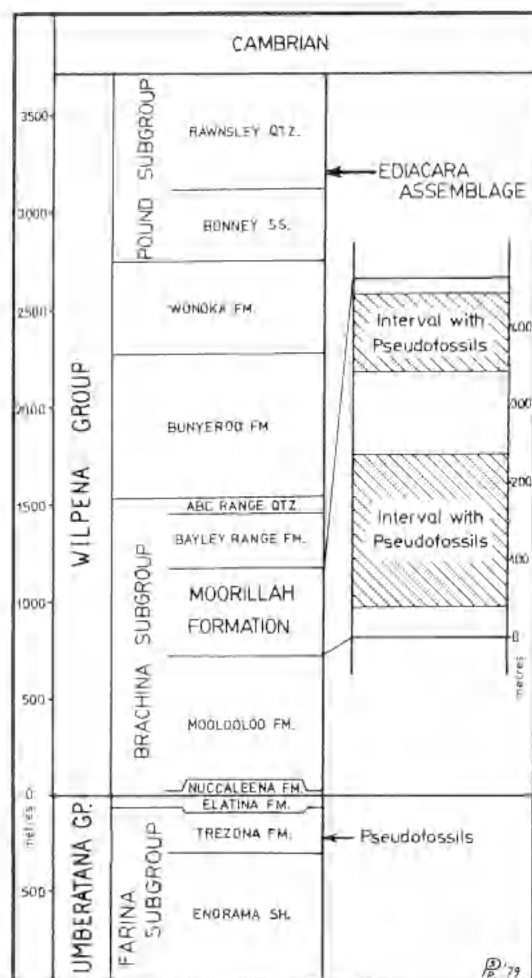


Fig. 2. Chart summarizing regional stratigraphy of youngest Precambrian succession in central Flinders Ranges, and showing stratigraphic intervals in which pseudofossils are found in relation to Ediacara assemblage. Only upper part of Umberatana Group shown. Pound Subgroup after Jenkins (1975b).

cryptalgal-laminites and associated stromatolites, oolitic limestones and intraformational limestone conglomerates interbedded in green siltstones (Thomson *et al.* 1976). It is of shallow water origin and comprises the uppermost unit of the Farina Subgroup, within the Umberatana Group, and is of early Marinoan age in terms of the local late Precambrian time-rock stratigraphy (Thomson 1969). It is succeeded by the approximately 60 m thick Elatina Formation which includes the tillitic deposits of the third and youngest glacial phase of the Adelaidean (Mawson 1949), and is part of the Willochra Subgroup of the Umberatana Group.

The Brachina Subgroup (Plummer 1978) of the Wilpena Group is a coarsening upward, dominantly clastic sequence with an average thickness of 1500 m. It rests mostly conformably though locally disconformably on the Elatina Formation. Lying within the Subgroup approximately 600 m above this glaciogenic unit is a 460 m thick sequence consisting predominantly of thinly interbedded red and purple shales and siltstones. This sequence is defined as the Moorillah Formation and commonly interposed within it are medium to thick beds of purple tuffaceous siltstone which often display intraformational conglomeratic textures, and lenticular crossbedded sandstones. Soft-sediment deformation structures are ubiquitous.

The structures which form the subject of this paper occur in two broad intervals within the Moorillah Formation. In Bunbinyunna Range (Fig. 1) several hundreds of specimens were observed in a broad zone spanning much of the basal half of the Formation. Very few specimens were observed near the top of the Formation in this area. Specimens were, however, moderately numerous near the top of the Formation at Mount Chambers Creek, 100 km to the northeast.

Repositories

Representative specimens are lodged in the collections of the University of Adelaide; catalogue numbers prefixed "A.U.". Studies were also made of a large collection of late Precambrian fossils obtained by Dr Hans Pflug, Giessen, West Germany, from the Nama Group of Namibia (South West Africa). These specimens, catalogued "Pf." are ultimately to be returned by Dr Pflug to the appropriate statutory body in Windhoek.

Description

The shape of the structures in vertical section is commonly cylindrical (Fig. 3A & E), with either a rounded to hemispherical base (Fig. 4A), or a flat, U-shaped base (Fig. 3F; Fig. 4G), which is often lopsided and with one or several central indentations (Fig. 4C, D, E & F). A sub-conical shape is also occasionally displayed (Fig. 3B & C). The upper part frequently expands outwards like the mouth of a trumpet. In section parallel to the bedding the structures display a circular to ovoid outline (Fig. 3C & D). The width of the structures (disregarding the trumpet-like upper rim) averages 6–8 cm, but

varies between 0.8 and 20 cm. The expanded mouth of the trumpet may reach over 30 cm. Their width is frequently less than their depth, with some specimens roughly twice as deep as wide. The depth may reach about 20 cm. Often their surface is nearly smooth, but on many a series of fine longitudinal ridges and grooves extends along the cylinder or cone and fans out on the trumpet-like upper rim. Occasionally these ridges and grooves continue across the base of the structure as radial markings (Fig. 4F). The significance of these markings is questionable, however, as they are often indistinguishable from, and grade into slickensides which also occur commonly within the matrix.

In the Moorillah Formation the structures are found within interbedded shales, siltstones and fine sandstones. In the majority of specimens the base of the structure is either sunken down into, or in close juxtaposition with the top of a siltstone or fine sandstone bed (Fig. 4C). The upper parts of the structures are often enveloped by laminated shales which sometimes include thin beds of siltstone. Where the siltstone below the structures is thin it is sometimes bowed downwards and there is a tendency for the shale laminae and thin siltstones subjacent to the sides of the structures also to be gently curved downwards (Fig. 3A & E; Fig. 4C & D). The uppermost part of the structures may terminate within shale, or be truncated or capped by another bed of siltstone which is often bowed upwards. The capping shale or siltstone participated in partially filling the structures. Rare specimens occur more or less entirely within shale (Fig. 3F).

Sections of the structures show that they had a complex history of infilling and subsequent compaction (Fig. 4C, D, E & G). Often the initial infilling consists of fine to coarse sand with angular or subrounded mud and silt clasts which came to rest in a sub-horizontal attitude, or sometimes in an edge-wise fashion (Fig. 4G). The sand infilling may show rather irregular erosional surfaces within, or grade upwards into laminated siltstone still containing occasional clasts. It is apparent that during de-watering of the surrounding matrix appreciable compaction occurred. The sandy material and silty infill of the forms seems generally to have behaved in a more competent manner and compacted less than the enveloping matrix, resulting in the observed

downward deformation of the external sediments below and upward deformation above (Fig. 3E). The silt laminae of much of the infill are frequently bowed upwards (Fig. 4C, D & E). The specimens from the Trezona Formation have a slightly calcareous silty infill, but otherwise show similar characteristics to the material from the Moorillah Formation.

Interpretation

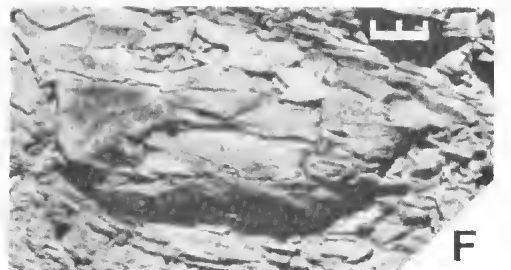
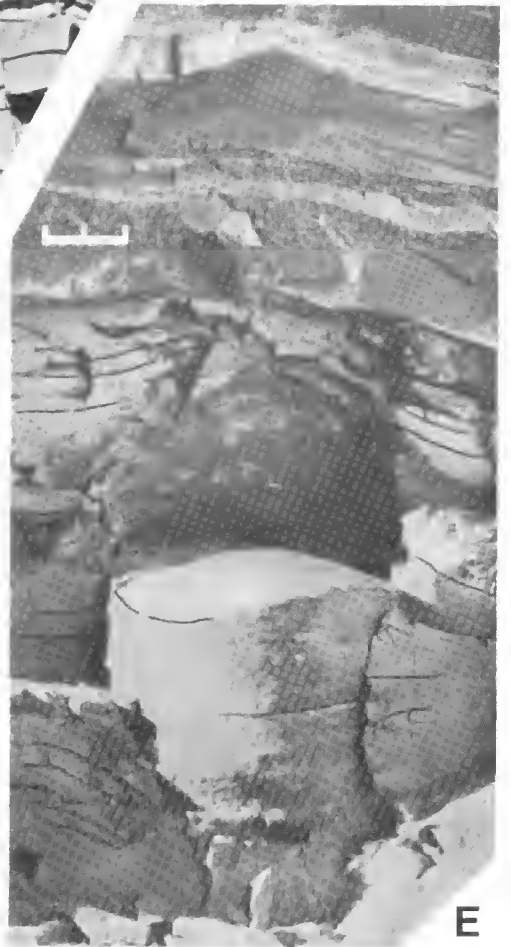
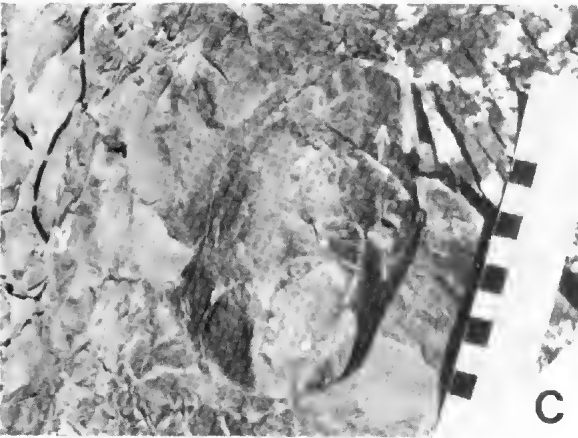
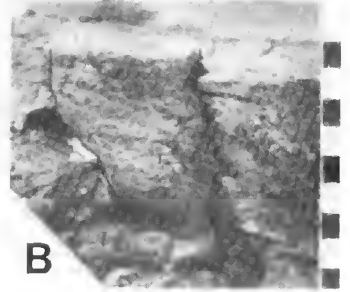
General

The nature of the infill indicates that the structures must have initially been hollows or holes within the sedimentation surface. These holes thus acted as traps for any coarse sediment being carried in traction before being buried by the more turbid finer sediment. A syngenetic origin is therefore envisaged for which either an organic origin, or production by inorganic processes, is possible.

Possible Organic Origin

Two possible organic origins could produce syngenetic structures similar to those described here. Firstly, the burial of dwelling or hiding burrows of actinian-like creatures could produce trace fossils resembling such forms as *Bergaueria*, or *Conostichus* Lesquereux. Alternatively, the preservation of eup- or sack-shaped animals could yield body fossils comparable to *Namalia* Germs, the "Ernettomorpha" of Pflug (1972a) or *Baikalina* Sokolov.

Frey (1970) describes the burrows of several living actinians as being considerably deeper than wide, or sometimes extremely elongate and occasionally branched. Shinn (1968) shows that adjacent to such burrows it is common to see a downwarping of the sediment lamination. In a study which Mangum (1970) made on the burrowing behaviour of the anemone *Phyllactis* Milne Edwards & Haire, she stated that rhythmic contractions of the column musculature manipulate the fluids of the column's hydrostatic skeleton to push the pedal disc into the substrate; "after the pedal disc reaches a hard substratum and sand surrounds the column (burrowing) ceases." The Lower Cambrian to Jurassic trace fossil *Bergaueria* is normally attributed to actinians burrowing and resting in this manner (Crimes *et al.* 1977). According to Alpert (1973) the depth of *Bergaueria* is less than or equal to its diameter, although Crimes *et al.* have observed deeper specimens in the Lower Cambrian of Spain. Externally,



some of our more shallow specimens are essentially indistinguishable from *Bergaueria* except for being generally greater in size. Sectioned specimens of *Bergaueria* from the early Cambrian of Alberta, Canada (Needler Arai & McGugan 1968; Germs 1972a) show a coarser, less regular internal lamination than our material, and sometimes show slumping which is presumed to reflect decomposition of the inhabitant of the burrow.

More conical examples among the present structures show a marked resemblance to another trace fossil, *Conostichus*, which is best known from the Mississippian-Pennsylvanian of North America and is also attributed to burrowing actinians (Chamberlain 1971; Crimes *et al.* 1977). *Conostichus* is a more or less conical burrow, tapering downwards, reaching about 11 cm in depth and 8 cm in diameter (Branson 1960) and variably marked by transverse constrictions and longitudinal furrows and ridges. The sides of *Conostichus* consist frequently of several "packed" layers apparently formed as the anemone wallowed in its burrow. Where it is assumed that the actinian abandoned the burrow abruptly, "shifting sand and debris filled the void with cross laminac" (Chamberlain 1971). Where the actinian apparently migrated upward in order to keep pace with sedimentation, the centre of the burrow may be filled with transverse sand laminae forming apically-convex concentric cones. While the present structures are sufficiently similar to *Conostichus* to suggest that they could have a broadly similar biological origin, that is formed by a "poly-poid" organism largely buried in the substrate, some important differences are apparent. Our structures are never observed to show layers of sediment plastered subjacent to their walls, and both the even lamination or the small erosional features within the infill show that the origin of this material is entirely sedimentary and not the packing behind a polyp moving upwards in its burrow.

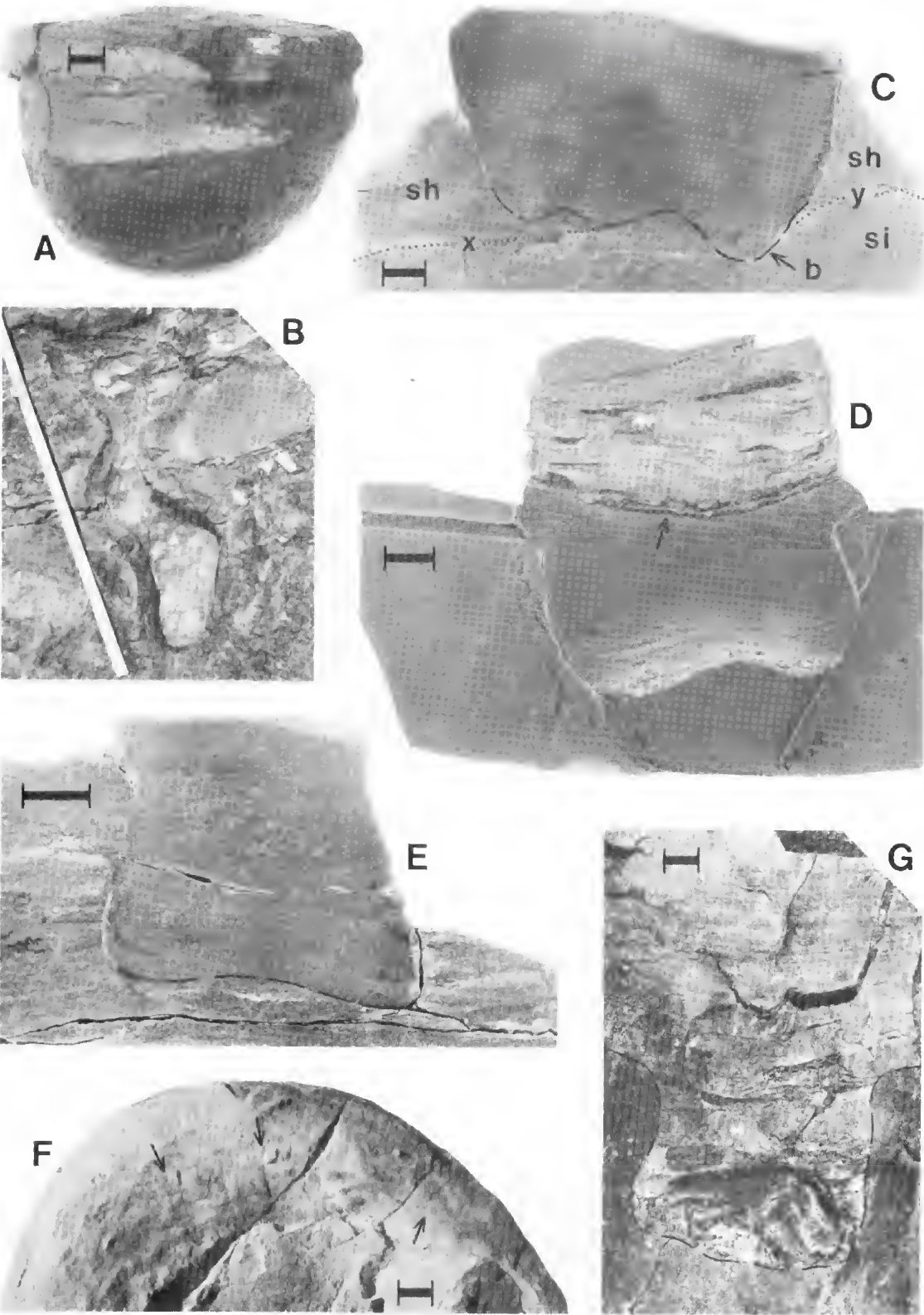
The second possible organic interpretation of the structures is that they are actual body

fossil remains, with the integument of the organism represented by the surface of parting between the enclosing matrix and the infilling material. They could thus be considered to be preserved as either an external mould and counterpart cast or as composite moulds in the terminology of McAlester (1962) and Wade (1968, 1971). As such, they might be further interpreted as showing affinities with a rather variable group of fossil forms known from the late Precambrian. These forms are *Namalia villiersiensis* Germs and the variety of specimens which Pflug (1972a) includes in the "Erniettomorpha", both from the Kuibis Subgroup of the lower part of the Nama Group, Namibia, and *Baikalina sessilis* Sokolov from the Ayankan Formation of the Upper Yudomian, on the Malyi Anai River, near Lake Baikal in Siberia.

Our structures strikingly resemble *Namalia villiersiensis* and the variable fossils Pflug (1972a) collectively describes as the "Erniettomorpha". Within this division Pflug includes 13 genera with 28 species in five subfamilies, four families and two orders (Glaessner 1979). One of us (Jenkins) has examined Pflug's material and considers that all the specimens he refers to as the "Erniettomorpha" belong to a single genus and species, *Ernietta plateauensis* Pflug; the other nominate taxa seemingly differ only in their completeness of preservation, their degree of compression, or the amount by which syndepositional erosional processes have truncated the upper parts of the buried remains (see also Glaessner & Walter 1975). The remains of *E. plateauensis* seem so similar to *N. villiersiensis* in their morphology, preservation and provenance that it is very likely that they are conspecific.

Ernietta is usually preserved in apparent life position with recorded field occurrences (Germs 1968, 1972a, 1972b) and specimens (Pflug collection) indicating that numerous individuals lived in close proximity to one another. The organism was essentially sack-shaped in form (Fig. 5A, B, C & E; Fig. 6A)

Fig. 3. Field photographs of uncollected pseudofossils; examples from lower part of Moorillah Formation, except D and F from upper part; scale divisions in cm. A, subcylindrical form with beds in adjacent matrix curved downwards at sides and thinned near base: Utanouna Creek. B, conical specimen: Utanouna Creek. C opening where conical specimen has eroded from matrix; upper edge of form apparently extended to line x-y and striations on mould of its surface are arrowed: Black Gap. D, external mould of large bowl-shaped form: Mount Chambers Creek. E, subcylindrical specimen showing gently domed ripple bedded sands above and downward deformation of beds near base: Utanouna Creek. F, profile of shallow structure within shale: Mount Chambers Creek.



and composed of several layers of soft tissue which could undergo ready deformation. The sack is inferred to have been attached at its closed end, either to the substrate, or very frequently to small clay galls or some other projection on the surface of the substrate (Fig. 5D & E; Fig. 6A). The several wall membranes of the sack were interconnected by thin, flexible, radially arranged, longitudinal septa whose position on any particular wall layer is marked by either narrow ridges or fine longitudinal grooves (Fig. 6B, C & D). The elongate tubular spaces so formed between the walls and the septa are frequently packed with silt or sand to form internal moulds. The upper and apparently open end of *Ernietta* terminates in a crenellate margin in the few rare instances where it is preserved. More frequently, however, it is found collapsed and deformed (Fig. 5A & E). This discussion of other details concerning the structure of this extraordinary organism fall outside the scope of the present work.

One of the most remarkable characteristics of *Ernietta* is its preservation, which is one of infilling comparable to the structures from the Flinders Ranges. Thus, sections of *Ernietta* may show a layered and graded sand or silt infill, with medium-grained sand at the closed end of the sack and very fine-grained sand near the apparent open end (Fig. 5C). Bedding surfaces indicate the original depositional orientation. Blebs of clay-rich material and limonite pseudomorphs, presumably after authigenic pyrite, are frequent in the infillings. The few specimens still within their original matrix are enveloped by medium-grained sand (now quartzite). The infilling of *Ernietta* does not, however, show the fine lamination usually observed in our structures.

Pflug (1972b 1974) orientated the "Ernietomorpha" in the reverse aspect to that sug-

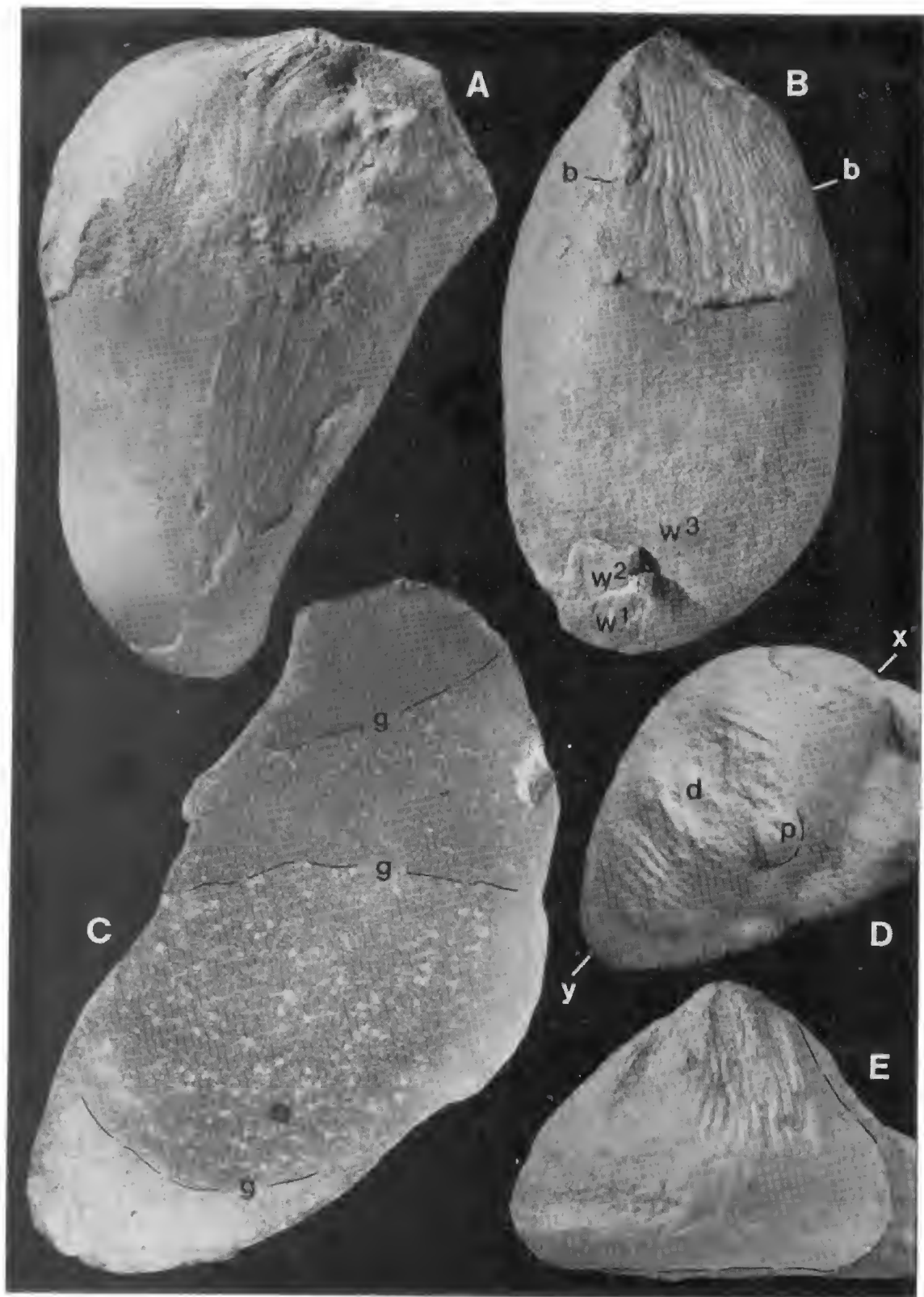
gested here, that is with the closed end of the sack upwards. Published data concerning their occurrence in the field (e.g. Germs 1968, 1972a) are ambiguous as to their orientation. Nevertheless, evidence from their distortion and layered infill is considered substantive of our interpretation.

From a stratigraphic viewpoint it is intriguing that the Kuibis Subgroup, which contains *Ernietta*, is succeeded by a sequence containing glaciogenic sediments and scraped and grooved bedding planes (parts of the Schwarzrand Subgroup) reflecting several cold phases of later late Precambrian glaciation in southern Africa (Germs 1972a, 1974; Kröner 1977; Kröner *et al.* 1980) and that our structures occur only relatively short stratigraphic distances both below and above the last late Precambrian glaciogenic deposits in the Flinders Ranges (parts of the Elatina Formation). However, the glacial events recorded in the Schwarzrand Subgroup are suggested to have been of local extent, and radiometric data of relevance for the Nama Group (Kröner 1977; preliminary data passed in personal communication between Professor Kröner and Dr Pflug; Kröner *et al.* 1980) together with fragmentary dating information from Australia reviewed by Williams (1975) suggests the likelihood that the Nama glaciations are significantly younger than the Elatina Formation.

The Siberian form *Balkalina sessilis* is apparently closely similar to *Ernietta*, but is too incompletely described for further comparison.

One objection to a biological origin is that if our forms did represent soft-bodied fossil organisms then the creatures must be interpreted as having maintained their life functions even during the time of their infilling, as their presumably soft integument would surely have collapsed flat if death were earlier.

Fig. 4. Photographs of infilling sediment and sections of pseudofossils and field photograph of depressions connected by gutters from lower part of Moorillah Formation at Utanouna Creek, except F, from same stratigraphic interval at Black Gap and G from loose boulder in Bunyeroo Creek. Bar-scales equivalent to 1 cm. A, side view of plug of infilling sediment of pseudofossil eroded free, A.U. No. 24731. B, field photograph of irregular depressions interconnected by gutters; end of ruler to hinge 50 cm. C-E, reflected light photographs of sections of pseudofossils; C, erosive base (b) of form closely juxtaposed with bedding interface (x-y) between siltstone bed (si) and overlying shale (sh), A.U. No. 24729. D, east infill with erosive surface, arrowed, and cone-shaped fractures (f-f) extending below: shale laminae in matrix down-turned at sides of structure, A.U. No. 24730. E, specimen with centrally domed base and domed, finely laminated silt infilling, A.U. No. 24728. F, underneath view of part of base of infilling plug of large pseudofossil with arrows indicating more or less radially arranged markings, A.U. No. 24733. G, broken section through pseudofossil within fine sandstone: infilling, also fine sandstone, includes numerous shale flakes, some of which are orientated in edge-wise fashion: overlying bed of laminated fine sandstone, A.U. No. 24734.



Maintenance of life during sedimentation seems manifestly impossible. This argument makes the explanation of the preservation of *Ernietta* difficult, but for this form it might be presumed that the onset of sedimentation was extremely rapid, perhaps in the form of a turbidity current which gave rise to the observed graded infill. In any event, the *Ernietta* organisms appear to have ultimately succumbed to sedimentation as their tops are variably pursed and compressed or overfolded (Fig. 5A & E). Our structures show no evidence of the multiple wall tissues present in *Ernietta*, nor definite evidence of septa or the precise and regular organization so characteristic of this fossil form. The most convincing explanation of the striations on the sides of our structures are as slickensides due to differential compaction. In a number of specimens the slickensided surfaces project into the matrix below the actual infill in the form of a more or less cone-shaped fracture (Fig. 4D).

The systematic position of *Nannalia*, the "Erniettomorpha" and *Baikaliina*, together with several other problematic Precambrian fossil organisms, was reviewed by Glaessner & Walter (1975), who suggested them to be related to their taxon *Arumberia hanksi*, from the Arumberia Sandstone in the Amadeus Basin, central Australia. Glaessner & Walter considered that while these forms could generally be referred to Pflug's (1970a, 1970b, 1971, 1972a, 1972b) division of the "Petalonamae", the formal application of this name was not to be recommended because of its hypothetical concept and various speculative implications applied to it. Thus they rejected the ideas of Pflug (1973, 1974) that the "Petalonamae" represent a peculiar branch of Precambrian evolution intermediate in position between the kingdoms of plants and animals. Nevertheless, Glaessner & Walter maintained that the forms just discussed and various Precambrian frond-like organisms show a general

similarity which implies an underlying taxonomic unity, and that the members of this grouping "may be classified provisionally as Coelenterata of uncertain systematic position".

This viewpoint is criticised by Jenkins and Gehling (1978) who suggested that the original concept of the "Petalonamae" may involve the artificial amalgamation of quite distinctive classes or even of separate phyla. Varying further interpretations of the Petalonamae are given by Ford (1979), Brasier (1979), Scrutton (1979) and Glaessner (1979), but this problem falls essentially outside the scope of the present study. Based on comparison with the geological studies and experimental work of Dżułyński & Walton (1965), "*Arumberia*" is considered by Brasier (1979) to be "probably a pseudofossil caused by turbid water flows". New widespread discoveries of "*Arumberia*" made by Dr B. Daily and Jenkins in central Australia (see also Kirschvink 1978), where the form is several times found in near association with coarse grained sandstones or conglomerates, provide a body of additional evidence supportive of Brasier's conclusion.

Probable Inorganic Origin

In an excellent review of inorganic cylindrical structures found within sediments, Bailey & Newman (1978) indicate that the usual postulated mechanisms for their formation involve early diagenetic upward-flowing springs or escaping pore waters (see also Quirke 1930; Hawley & Hart 1934; Gabelman 1955; Conybeare & Crook 1968). Such structures are frequently filled with sediment of similar grain size, sorting and texture to the enclosing (siltstone or sandstone) matrix, or show a crude coarsening in grain size towards the centre of the cylinder. Occasionally, even an inverted cone-in-cone arrangement of silt and sand lamination can occur (see Dionne & Laverdière 1972; Gangloff 1974). Often the lower end of the cylinder is irregular and shows

Fig. 5. Remains of *Ernietta plateauensis* Pflug, 1966, from Kuibis Subgroup of lower part of Nama Group, Namibia; all natural size. A, side of nearly complete specimen viewed along line of wider transverse axis; uppermost parts show evidence of overfolding, Pf. No. 178. B, side of specimen viewed normal to wider transverse axis; at least three separate wall membranes (W_1 , W_2 and W_3) shown by internal moulds of sand, enigmatic "budding" suture occurs along b-b, Pf. No. 182. C, longitudinal section of sand infilling central cavity showing layers of progressively finer sediment and depositional surfaces (g) presumably reflecting intermittent stages of infilling and orientation of organism at each stage; dark square and spots limonite after authigenic pyrite, light coloured edge of the infilling due to weathering Pf. No. 308. D, view of base of specimen showing deformed area (d) and nipple-like prominence (p) which may represent the point of attachment of the organism; zig-zag suture along line x-y, Pf. No. 99. E, side view of specimen with some of enclosing matrix; infilling individual collapsed downwards, with base flattening and upper part pursing inwards, Pf. No. 287.

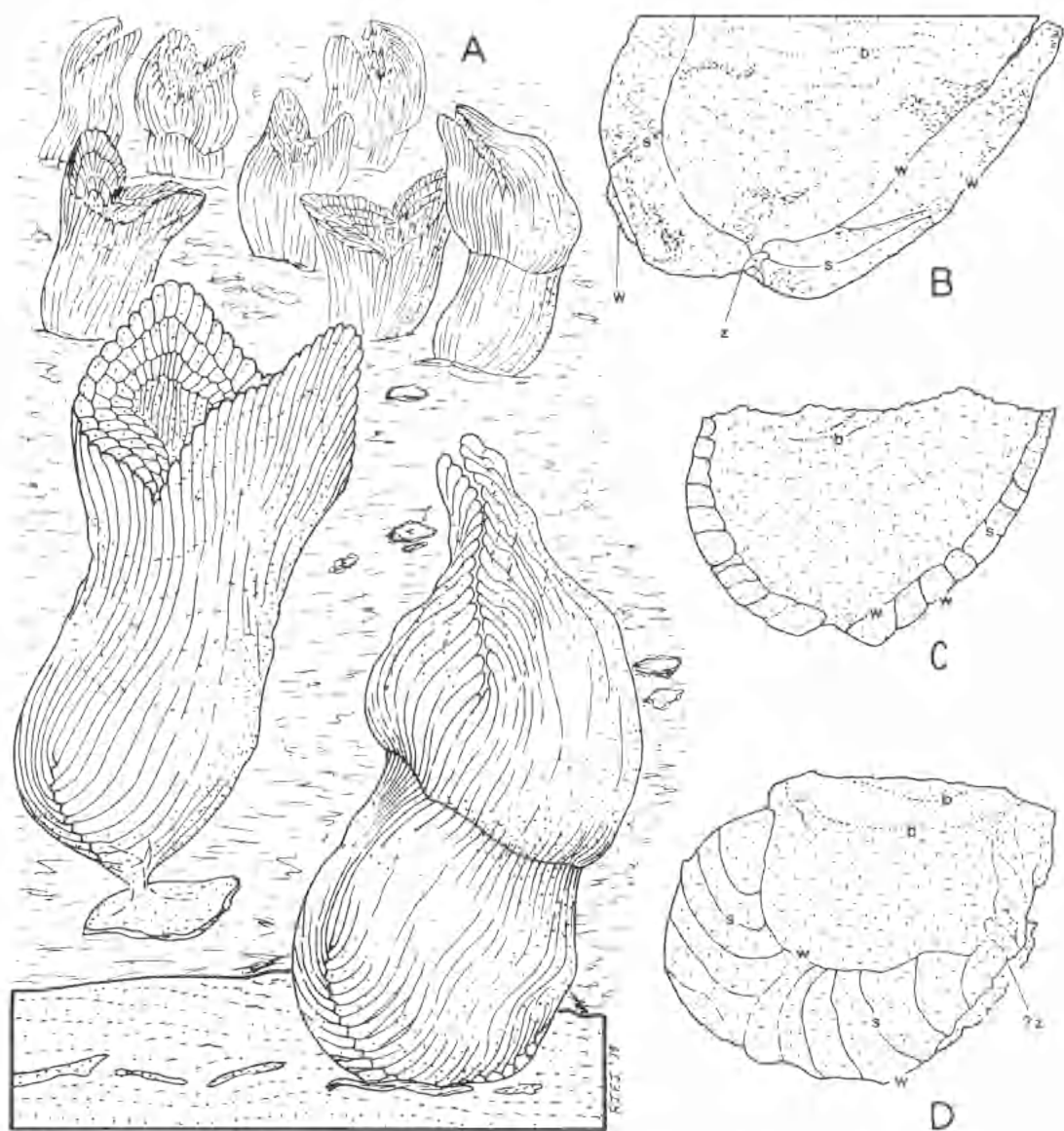


Fig. 6. *Ernieella plateauensis* Pflug, 1966. A, reconstruction of group of individuals living on sandy Precambrian sea bottom. Several possible alternative, but not necessarily mutually exclusive, reconstructions of individuals shown. Youthful specimens evidently attached to mud galls or other prominences on sea bottom, more mature specimens may have lived with basal parts buried in substrate. Outermost membrane seems to have been caul-like and only faintly showing underlying longitudinal structure. "Mouth" sometimes preserved broadly flared, or more frequently collapsed or pursed. Individuals of all sizes may show enigmatic transverse suture or possible zone of "budding" at about half their length. About .7 natural size. B-D, sketches of sectional cuts through actual specimens: b, traces of bedding in matrix (impure sandstone or quartzite); r adhering thin sliver of rock; s, septal membranes evidenced by surfaces of parting or thin limonite stained traces; w, similarly evidenced wall membranes; z, known or inferred position of basal zig-zag suture; all $\times 1.5$. B, sublongitudinal section almost normal to zig-zag axis, three wall membranes evidenced. PF. No. 120. C, section of another specimen almost transverse to longitudinal surface markings. D, section of different specimen cut oblique to longitudinal surface markings.

fissure fillings. In the present structures from the Flinders Ranges, however, the frequently fine lamination of the more silty phases of the infilling shows no evidence of disruption other than slight deformation during compaction, and the thin sand beds which often occur at the base of the cylinder show no sign of fissuring or disruption such as might be expected with the rapid escape of fluids. Thus our structures were evidently not formed by the upward escape or flowage of pore fluids. Also, the syngenesis of these structures eliminates an epigenetic concretionary origin. Such syngenetic structures could, therefore, only be formed inorganically as toroids or pot-casts; these names both essentially referring to the casts of circular scour pits.

In past literature, such scour pits are often suggested to have been formed by whirlpool action generated along the boundary between currents flowing in opposite directions. As such they might be expected to occur in high energy shallow-water environments in both marine and non-marine realms. According to Conybeare & Crook (1968), circular toroids are usually wider than deep. The external morphology of their casts is suggested to be characteristically swirled, like that of a "folded bun", generally with a smooth surface, although the formation of roughly concentric patterns by scouring is common. Internally, toroid casts may display structural and textural homogeneity.

Our structures show a marked resemblance to the "rippled toroids" described by Dorr & Kauffman (1963) from the Mississippian Napoleon Sandstone of southern Michigan. They considered these toroids to have been "formed by the action of vortex currents on unconsolidated sand in shallow water of the inner sublittoral zone" and supported their findings by inducing vortices in a water-filled, sand-floored box and producing artificial toroids. Some of the structures they described were elongate, oblique cones, a shape occasionally shown by our material.

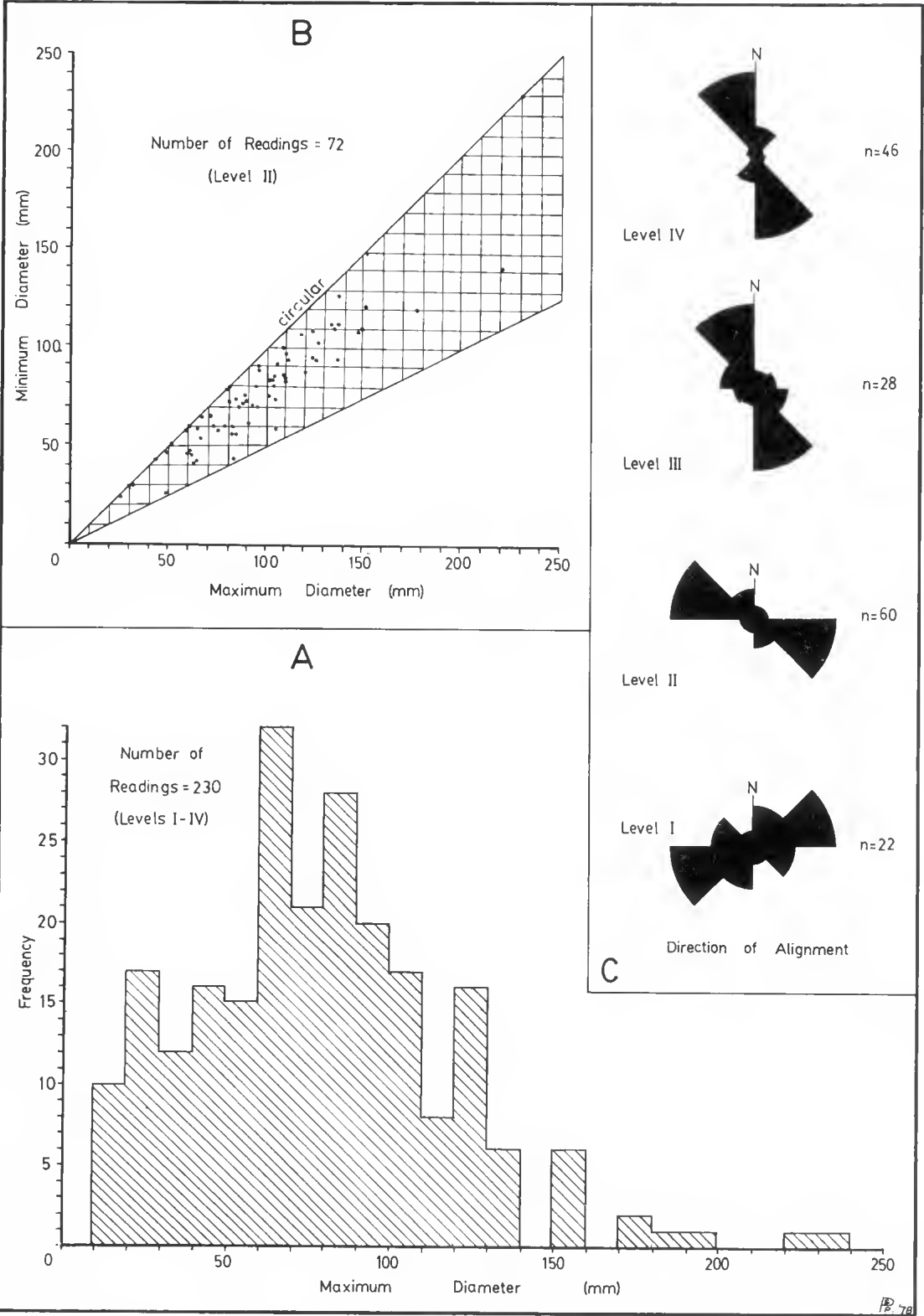
This precise explanation seems inapplicable with respect to our structures for several reasons. Dorr & Kauffman considered that the environment of deposition of the Napoleon Sandstone was one of relatively high energy and this is consistent with the texture of the rock (sand). Our structures occur within a variety of lithotypes representing mud to fine sand grades, reflecting microenviron-

ments of varying energy levels, and presumably mostly of rather low energy. The vortex hypothesis invoked by these authors implies tidal shear or near-shore phenomena which, by their very nature, must be restricted to a relatively narrow belt parallel to the palaeo-coast. We, however, have located our structures at geographic separations of 20 km parallel to the inferred depositional strike and perhaps 60 km at right angles to it. Also, our forms occur at various levels over a total stratigraphic thickness in excess of 1400 m.

Aigner & Futterer (1978) and Aiger (1978) document and explain inorganic pot-casts and gutter-casts from the Muschelkalk of south-west Germany. Some of the pot-casts which they figure (i.e. Aigner & Futterer 1978, figs. 3A, A¹, D, D¹ and E) are identical in shape and internal layering to the Flinders Ranges specimens, except that the coarse material at the base of the "pots" consists of shell debris rather than clay galls. The Muschelkalk pots may be packed within an edgewise conglomerate of shells similar to the edgewise conglomerate of mud flakes present in some of our specimens (Fig. 4G).

On the basis of flume experiments Aigner & Futterer attribute the Muschelkalk pot-holes to the erosive effects of eddy currents forming in shell-filled depressions due to the influence of a steady or increasing unidirectional current over the general surface of the substrate. They note that such pots are unknown on present-day tidal flats and consider that their origin is entirely submarine. The implications of this are at some variance with Plummer's (1978) finding that on the basis of such structures as flat-topped ripples, interference ripples and shallow channels with ebb-oriented asymmetric ripples, parts of the Moorillah Formation in which our structures occur frequently accumulated in a low intertidal mud flat environment. However, we did not observe any sedimentological structures in direct association with the pot-casts that would imply emergence.

An attractive aspect of this explanation for the Flinders Ranges structures is that sometimes the pot-casts are peculiarly coalesced or joined by uneven trough-like forms (Fig. 4B) which are exactly paralleled in the Muschelkalk material (Aigner & Futterer 1978, figs. 3B, C and F). In rare instances there may even be evidence of a ripple hollow or other depression in which the clay galls that



formed the erosive tools may have originally accumulated (Fig. 3A).

Measurements of the diameter of the pot-casts in the Flinders Ranges (Fig. 7A & B) show a range of variability quite comparable to gutter-casts studied by Aigner & Futterer and the depth of specimens is similar. A histogram of diameter against frequency (Fig. 7A) shows a somewhat skewed distribution with the modal diameter at 6–7 cm. A suggestion of a polymodal component in this histogram probably reflects the observation that specimens of the pot-casts on given bedding planes tend to be closely similar in size, a likely indication of their nearly simultaneous generation. Karez *et al.* (1974) describe how a field of small pits (individually reaching up to 9 mm diameter) may form on freshly deposited clay under the influence of a current, and it may be possible that such depressions serve as a nucleus for the subsequent formation of pot-holes.

The study of Aigner & Futterer also demonstrates a very marked preferred orientation for the Muschelkalk gutter-casts, parallel to the coastline and basin axis. Our pot-structures are usually ovoid in outline (Fig. 7B) and measurements on four bedding-planes in ascending stratigraphic order at Utanouna Creek also demonstrate a marked preferred orientation for any given bedding plane (Fig. 7C), though this direction changes by 90° between the lowest and the third surfaces studied. The more or less east-west orientations for Levels I and II are approximately normal to the palaeodepositional trends for the Flinders Ranges area, whilst the N.N.W.–S.S.E. directions for Levels III and IV are roughly parallel to the basin axis and (western) shoreline (e.g. see Plummer 1978).

The individual pot-casts are spaced on bedding planes at intervals of several tens of centimeters to several meters. In rare instances specimens are grouped on part of a bedding plane, while none are present on the remainder of the surface. Dorr & Kauffman (1963) pointed out that the "rippled toroids" which they described also show a patchy distribution. Similarly Norrman (1964) indicated a

clumped distribution for modern day pot-holes eroded into a clay lake bottom.

Associated pseudofossils and oldest local record of metazoans

Glaessner (1969) described the complex trace-like marking *Bunyerichnus dalgarnoi* from the base of the presently recognised Moorillah Formation at Bunyeroo Gorge. He considered that this marking may have been made by an animal related to a primitive mollusc without a shell. Large bedding plane exposures are a persistent feature of many outcrops of the Moorillah Formation at this locality, but despite extensive searches no new finds of *B. dalgarnoi* have been made during the decade since its discovery. After critical examination of *B. dalgarnoi*, Jenkins (1975a) suggested that it is a composite of primary impressions occurring on two separate bedding planes, and thus unlikely to be of metazoan origin. The great frequency with which inorganic tool markings occur in this formation led Jenkins to consider it to be "a unique accidental set of markings made by a tethered implement moved by the current". The implement may have been a small mud clast caught in a tassel of twisted algal threads. It is suggested to have moved in a series of small jumps in several arcuate swaths to leave overlapping, curved bands of more or less regular, transverse imprints marking successive bedding planes. Thalys-bearing, ribbon-like algae, which might have provided the tether, appear in the Riphean of the U.S.S.R. and form accumulations grading into sapropelic laminae and films in the Vendian (Sokolov 1977).

Small circular markings on a bedding plane of a single loose block of rock found within the Moorillah Formation have been considered as structures formed by escaping gas (Plummer 1980).

The oldest probable record of metazoans in the Flinders ranges is of markings resembling small medusoids and fine sinuous trails found by Dr Mary Wade at Brachina Gorge within the Bonney Sandstone (previously the "Red Pound Quartzite") which is the lower formation of the Pound Subgroup (Wade 1970, p.

Fig. 7. Measurements of pseudofossils at Utanouna Creek, Bunbinyunna Range. A, histogram of maximum transverse diameter of specimens plotted against frequency; specimens occur on four large bedding planes, levels I–IV in ascending stratigraphic order. B, plot of maximum and minimum transverse diameters of individual specimens occurring on level II. C, direction of orientation of longer transverse axis of ovate specimens plotted for each bedding plane.

92). Other finds of Precambrian metazoans in Australia are apparently either approximately equivalent in age to the Ediacara assemblage *sensu strictu*, or are likely of younger age as is inferred for the Mt Skinner "fauna" of the Amadeus and Georgina Basins (see Wade 1969; Daily 1972; Kirschvink 1978). It thus becomes timely to consider why the several thousand metres of Marinoan or youngest Precambrian sediments which precede the Pound Subgroup in the Flinders Ranges, and which are well exposed and otherwise occur extensively throughout the Adelaide Fold-Belt, are apparently barren of metazoan fossils. Numerous stratigraphical and sedimentological studies generally imply marine origins for much of this succession (Thomson 1969; Thomson *et al.* 1976; Plummer 1978). Arguments that the facies may not have been suitable for the preservation of small soft-bodied remains (cf. Glaessner 1972) are not fully convincing as finely laminated beds preserving the smallest inorganic tool-markings (ca. 0.5 mm) are frequent, and Wade (1968, 1970) has found that the conditions needed for the preservation of a soft-bodied assemblage were not particularly stringent. Indeed the Ediacara assemblage *sensu lato* is now known to occur in quite variable facies at different World localities.

An extensive literature concerns supposed finds of either body fossils or trace fossils predating the Ediacara assemblage *sensu lato*, but subsequent studies have led frequently to a questioning of the interpretation or sometimes the age of these reported occurrences (Glaessner 1969, 1979 and pers. comm.; Cloud 1973, 1978; Cloud *et al.* 1980; Sokolov 1977; Yakobson & Krylov 1977). Other of these finds continue to be cited as possible evidence supportive of ideas of a gradualistic evolution of early metazoans (e.g. Glaessner 1972, 1979; Bengtson 1977; Brasier 1979). The studied record of the sequences in the Flinders Ranges does not provide evidence of an extended early history for the metazoans.

Rather negative evidence and the known occurrence of fossils in the Flinders Ranges lend support to ideas such as those of Stanley (1973, 1976a, 1976b) suggesting a late radiation of metazoans, predicted on a basis of ecological modelling, or to an exponential increase in animal life from the late Precambrian to the Cambrian, shown by analysis of age data and counts of recognized taxa (Sepkoski

1978, 1979). Stanley considered that the early radiation of eukaryotes may have been inhibited by the saturation effect of Precambrian algal systems and suggested that the advent of cell-eating heterotrophy triggered a "kind of self-propagating feedback system of diversification" culminating in the initial major radiations of both the metaphtytes and metazoans.

Recently Choubert & Faure-Muret (1980) assigned a middle Riphean age to the rocks containing Precambrian metazoan fossils on the Avalon Peninsula, Newfoundland, and at Charnwood Forest, England. This finding is patently incorrect, and not only overlooks lines of geological evidence which suggest that these rocks are late Precambrian (Williams & King 1979; Patchett *et al.* 1980), but ignores a 20 year cycle of research documenting Vendian or Ediacaran affinities for the genera *Charnia* Ford and *Charniodiscus* Ford present in the fossil assemblages (Glaessner 1977, 1979).

Conclusions

The present study describes Precambrian structures which have a relatively complex genesis and show resemblances to certain cylindrical to conical fossil burrows, as well as to sack-shaped, longitudinally striate body fossil remains of comparable age. However, these resemblances appear to be fortuitous and the true origin of the structures is suggested to be as erosive pits formed by vortices induced by episodic currents and the scouring action of trapped mud galls. The hydrodynamic conditions leading to their formation are not fully understood and to our knowledge no such structures have yet been described from present day, marine, sub-tidal environments. The degree of resemblance between these pseudofossils and several burrow forms and sack-shaped body fossils emphasizes that a variety of both inorganic and organic processes may lead to the formation of closely similar structures which may even show degrees of gradation. The corollary of this finding is that the description of such kinds of Precambrian structures and the assignment of a particular genesis, especially one of biological origin, should be approached with caution.

The finding of these structures and recognition of other associated pseudofossils suggests that true indications of Metazoa are restricted to the highest part of the local

Precambrian sequence, thus providing negative evidence supporting recent theories that postulate a late evolution or radiation of animal life towards the close of the Precambrian.

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SONDEROPHYCUS AND THE TYPE SPECIMEN OF PEYSSONNELIA AUSTRALIS (CRYPTONEMIALES, RHODOPHYTA)

BY *H. B. S. WOMERSLEY & D. SINKORA*

Summary

The type specimen of *Peyssonnelia australis* Sonder in MEL is a *Peyssonnelia* and is distinct from the taxon known as *Sonderophycus australis* (Sonder) Denizot. The latter, which is based on *P. australis* Sonder, is distinct generically from *Peyssonnelia* and is therefore re-described as *Sonderopelta coriacea* gen. et sp. nov. *P. australis* Sonder is an earlier name for *P. gunniana* J. Argadh but a synonym of *P. capensis* Montagne.